EE101: RLC Circuits (with DC sources)

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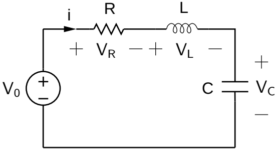
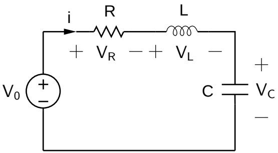
Series RLC circuit





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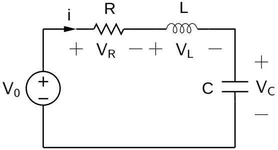

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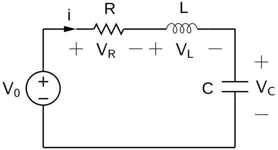

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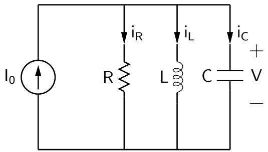
i.e., $\dfrac{d^2 i}{dt^2} + \dfrac{R}{L}\,\dfrac{di}{dt} + \dfrac{1}{LC}\,i = 0\,,$

a second-order ODE with constant coefficients.

Parallel RLC circuit



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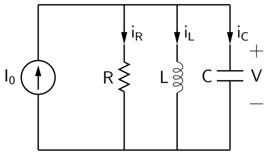

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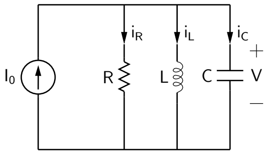

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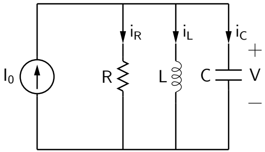

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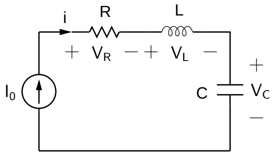
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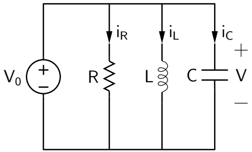
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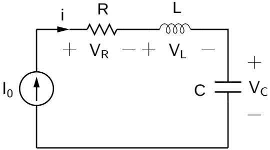

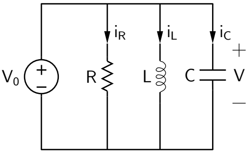

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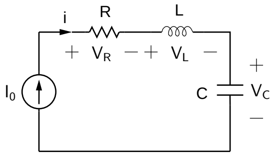

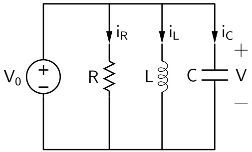

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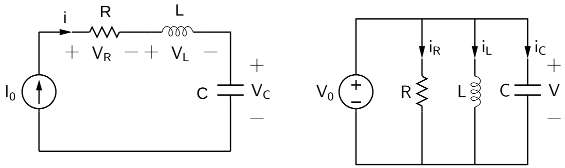

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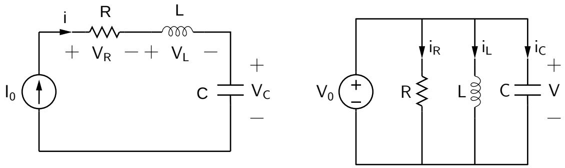

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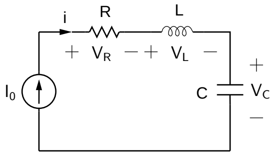

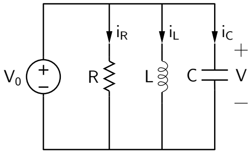

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* The above equations hold even if the applied voltage or current is not constant, and the variables of interest can still be easily obtained without solving a differential equation.

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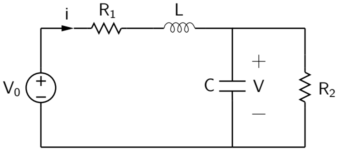

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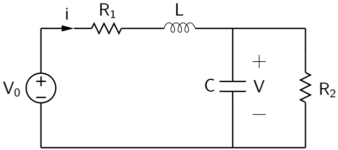

$$V_0 = R_1\, i + L\,\frac{di}{dt} + V \tag{1}$$

$$i = C\,\frac{dV}{dt} + \frac{1}{R_2}\,V \tag{2}$$

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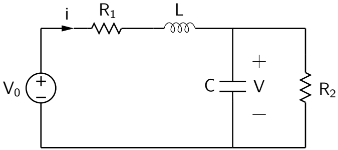

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Substituting (2) in (1), we get

$$V_0 = R_1 \left[CV' + V/R_2 \right] + L \left[CV'' + V'/R_2 \right] + V\,, \tag{3}$$

$$V'' \,[LC] + V' \,[R_1 C + L/R_2] + V \,[1 + R_1/R_2] = V_0\,. \tag{4}$$

General solution

Consider the second-order ODE with constant coefficients,

$$\frac{d^2y}{dt^2} + a\,\frac{dy}{dt} + b\,y = K \text{ (constant)}\,.$$

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$$y(t) = y^{(h)}(t) + y^{(p)}(t)\,,$$

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In the context of RLC circuits, $y^{(p)}(t)$ is the steady-state value of the variable of interest, i.e.,

$$y^{(p)} = \lim_{t\to\infty} y(t),$$

which can be often found by inspection.

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For the homogeneous equation,

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we first find the roots of the associated *characteristic equation*,

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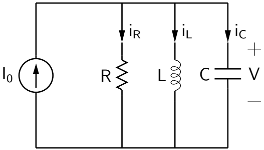
Parallel RLC circuit



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C=1 μF

L=0.44 mH

I_0 = 100 mA

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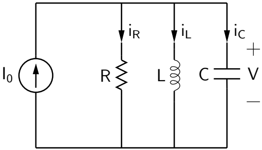

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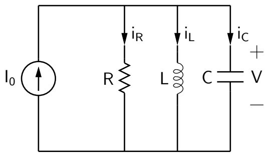

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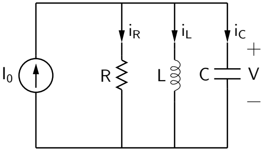

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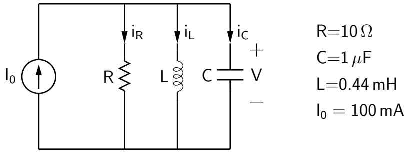

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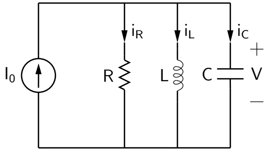

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where $\tau_1 = -1/r_1 = 15.4\,\mu s$, $\tau_2 = -1/r_1 = 28.6\,\mu s$.

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From (1) and (2), we get the values of A and B, and

$$V(t) = -3.3\,[\exp(-t/\tau_1) - \exp(-t/\tau_2)]\ \ V\,. \tag{3}$$

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$$A + B = 0\,. \tag{1}$$

Our other initial condition is $i_L(0^+) = 0\ A$, which can be used to obtain $\dfrac{dV}{dt}(0^+)$.

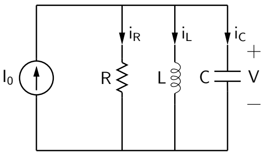
$i_L(0^+) = I_0 - \dfrac{1}{R}\,V(0^+) - C\,\dfrac{dV}{dt}(0^+) = 0\ A$, which gives

$$(A/\tau_1) + (B/\tau_2) = -I_0/C\,. \tag{2}$$

From (1) and (2), we get the values of A and B, and

$$V(t) = -3.3\,[\exp(-t/\tau_1) - \exp(-t/\tau_2)]\ \ V\,. \tag{3}$$

(SEQUEL file: `ee101_rlc_1.sqproj`)

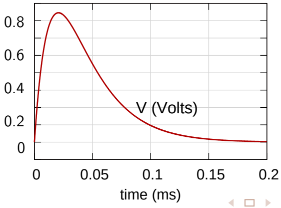


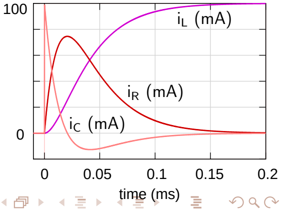
R=10 Ω

C=1 μF

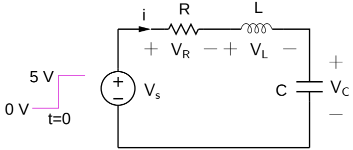
L=0.44 mH

I_0 = 100 mA



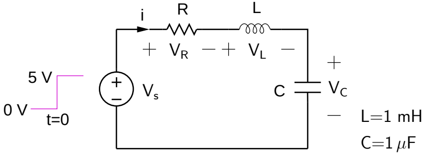


Series RLC circuit: home work

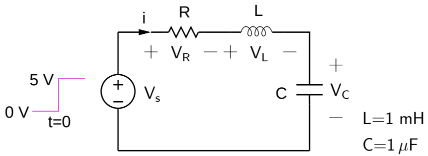


L=1 mH

C=1 μF

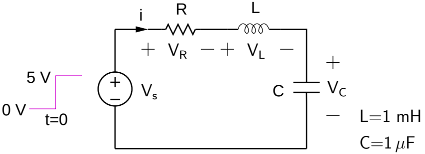


(a) Show that the condition for critically damped response is $R = 63.2\,\Omega$.



(a) Show that the condition for critically damped response is $R = 63.2\,\Omega$.

(b) For $R = 20\,\Omega$, derive expressions for $i(t)$ and $V_L(t)$ for $t > 0$ (Assume that $V_C(0^-) = 0\ V$ and $i_L(0^-) = 0\ A$). Plot them versus time.



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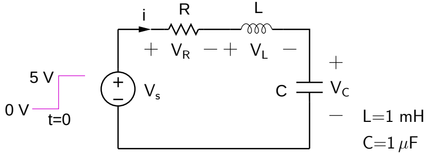

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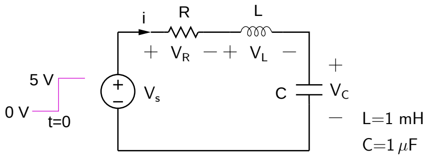
(d) Compare your results with the following plots.
(SEQUEL file: `ee101_rlc_2.sqproj`)



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